SECTION 16450

SECONDARY GROUNDING

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NOTE: Edit this Section to match project requirements. Where conductor sizes are specified, they are minimum sizes required by the LANL electrical Design Standards.

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PART 1 GENERAL

1.1 SECTION INCLUDES

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NOTE: Edit SECTION INCLUDES to match project requirements.

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A. Main Grounding Electrode System (Lightning Protection System grounding is specified in Section 16670.)

B. Circuit and System Grounding

C. Enclosure and Equipment Grounding System

D. Isolated Ground System

E. Communications System Grounding

F. Signal Reference Grid

G. Overhead Line Grounding

H. Underground Distribution System Grounding

1.2 SUBMITTALS

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NOTE: Edit SUBMITTALS to match project requirements.

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A. Submit the following in accordance with the requirements of Sections 01300 and 01700.

1. Catalog Data: Submit catalog data for grounding conductors, grounding clamps, grounding bushings, grounding plates, grounding bars, chemical ground rods, exothermic weld materials, compression grounding connector materials, and signal reference grid materials.

2. Shop Drawings: Submit shop drawings for signal reference grid fabrication and installation.

3. Project Record Documents: Submit project record documents to include specified certifications and field test reports of installed grounding systems.

1.3 QUALITY ASSURANCE

Furnish and install grounding systems in accordance with ANSI/NFPA 70 - *National Electrical Code* and this specification section.

PART 2 PRODUCTS

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NOTE: Edit 2.1 to match project requirements.

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2.1 GROUND ROD

A. Provide UL listed ground rod(s) as indicated on the Drawings.

B. Furnish ground rods with high-strength steel core and electrolytic-grade copper outer sheath, molten welded to core, approximately 10 feet long, 3/4 inches in diameter.

C. Manufacturers: Blackburn, Thomas & Betts, Harger

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NOTE: Edit to 2.2 to match project requirements.

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2.2 CHEMICAL GROUND ROD

A. Provide UL listed chemical ground rod(s) as shown on the Drawings.

B. Furnish chemical ground rods fabricated from Type K copper tubing approximately 10 feet long, 2 inches in diameter and containing a hygroscopic electrolyte material. Furnish each chemical ground rod with a 24 inch long #4/0 copper pigtail, a protective cover box, and Bentonite clay backfill material.

C. Manufacturers: Lyncole Industries, Inc., LEC Inc., Superior Grounding Systems

2.3 GROUND ELECTRODE CABLE

A. Provide No. 4/0 AWG bare stranded, soft temper copper cable that conforms to ASTM B8, *Standard Specification for Concentric-Lay Stranded Copper Conductors*.

2.4 GROUND ELECTRODE BACKFILL MATERIAL

A. Provide a Bentonite clay or equivalent commercial ground enhancement backfill material for ground rods and cable type electrodes.

B. Backfill material, when at 300% moisture content ((weight of water/weight of material)x 100), shall have a resistivity of approximately 250 ohm-cm and a pH of 8 to 10.

C. Manufacturers: WYO-BEN Inc, ERICO

2.5 GROUNDING CONDUCTORS

A. Provide UL Listed THHN/THWN insulated copper wire.

B. Use solid grounding conductors No. 10 AWG and smaller where not subject to vibration or repeated flexing.

C. Use stranded grounding conductors for No. 8 AWG and larger.

D. Use stranded grounding conductors where subject to vibration or repeated flexing. Use stranded grounding conductors in flexible conduit at motor connections.

E. Color code grounding conductors as follows:

1. Equipment ground:

a. Conductors No. 6 AWG and smaller: Green colored insulation.

b. Conductors No. 4 AWG and larger: Black colored insulation with 3/4 inch wide band of water and oil-resistant green plastic adhesive tape.

2. Isolated ground:

a. Conductors No. 6 AWG and smaller: Green colored insulation with continuous yellow stripe.

b. Conductors No. 4 AWG and larger: Black colored insulation with 3/4 inch wide bands of water and oil-resistant green and yellow plastic adhesive tape.

2.6 GROUND BAR

A. Provide ground bar, 12 inches long or greater length as indicated on the Drawings, fabricated from 1/4 inch thick, 4 inch wide copper stock with 1.75" x 1.75" NEMA bolt hole pattern. Mount ground bar on 2700 volt standoff insulators.

B. Manufacturers: ERICO Cadweld, Harger.

2.7 GROUND PLATES

A. Provide UL listed ground plates designed for flush mounting in concrete structures. Furnish copper alloy castings with four 1/2 inch threaded holes at 1.75" x 1.75" NEMA spacing and a #4/0 AWG welding stud or compression connection.

B. Manufacturers: ERICO Cadweld, Burndy.

2.8 GROUND CONNECTORS

A. Provide UL listed copper alloy connectors with silicon bronze hardware for making cable to pipe connections.

B. Manufacturers: Burndy, O.Z.

2.9 CONDUIT GROUNDING BUSHINGS

A. Provide UL listed, galvanized malleable iron, 150°C rated insulated throat grounding bushings with lay-in type ground cable lugs.

B. Manufacturers: O.Z., Thomas & Betts

2.10 EXOTHERMIC WELD GROUNDING CONNECTIONS

A. Provide molds and welding material for making exothermic weld connections.

B. In interior locations and in vaults, use low smoke emission type welding material.

C. Match mold and weld material to material types, shapes and sizes to be joined.

D. Manufacturer: ERICO Cadweld

2.11 COMPRESSION GROUNDING CONNECTIONS

A. Provide UL listed wrought copper connectors, terminals and splices for making compression grounding connections.

B. Furnish connectors that have been tested successfully according to the requirements of IEEE Std. 837 - *IEEE Standard for qualifying Permanent Connections Used in Substation Grounding*.

C. Provide hydraulic compression tools and dies that match the connectors.

D. Match connector and die size to material shapes and sizes to be joined.

E. Manufacturer: Burndy

2.12 SIGNAL REFERENCE GRID (SRG)

A. Furnish signal reference grid (SRG) as indicated on the Drawings.

B. Provide a pre-fabricated grid of 2 inch wide by 26 gage copper strips on two foot centers with all crossover connections factory welded.

C. Provide low impedance risers consisting of 2 inch wide by 26 gage copper strips for connecting equipment to the signal reference grid.

D. Manufacturers: ERICO Cadweld, Harger

PART 3 EXECUTION

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NOTE: Edit PART 3 to match project requirements.

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3.1 GENERAL

A. Comply with the requirements of ANSI/NFPA 70, this Section and the Drawings.

B. Do not use the grounding systems specified in this section for lightning protection grounding. A separate lightning protection grounding system is specified in Section 16670. Bond the lightning protection ground to the main electrode system at the service entrance ground bar.

C. Clean contact surfaces to which ground connections are to be made. Remove non-conductive coatings such as paint, enamel, oxidation and oil film.

D. Use the following connection methods unless otherwise specified or indicated on the Drawings:

1. Use exothermic weld grounding connections for underground or concealed connections of dissimilar materials.

2. Use exothermic weld or compression grounding connections for underground or concealed connections of like materials.

3. Use exothermic weld, compression, or bolted grounding connections for accessible connections.

4. Use high strength silicon bronze bolts, nuts, flat washers and toothed lockwashers for making bolted ground connections.

E. Tighten grounding and bonding connectors and terminals, including screws and bolts, in accordance with manufacturer's published torque tightening values for connectors and bolts. Where manufacturer's torquing requirements are not indicated, tighten connections to comply with torque tightening values specified in UL 486A and UL 486B. Use a calibrated torque wrench.

F. Use hydraulic compression tools to provide the correct circumferential pressure for compression connectors. Use tools and dies recommended by the manufacturer of the connectors. Provide embossing die code or other standard method to make a visible indication that a connector has been adequately compressed.

G. Install exothermic welds in accordance with manufacturer's instructions and recommendations. Welds that are puffed up or that show convex surfaces indicating improper cleaning are not acceptable.

H. Make connections in such a manner as to minimize possibility of galvanic action or electrolysis. Select connectors, connection hardware, conductors, and connection methods so metals in direct contact will be galvanically compatible.

1. Use electroplated or hot-tin-coated materials to assure high conductivity and make contact points closer in order of galvanic series.

2. Make connections with clean bare metal at points of contact.

3. Make aluminum to steel connections with stainless steel separators and mechanical clamps.

4. Make aluminum to galvanized steel connections with tin-plated copper jumpers and mechanical clamps.

5. Coat and seal connections involving dissimilar metals with inert material such as red lead paint to prevent future penetration of moisture to contact surfaces.

3.2 MAIN GROUNDING ELECTRODE SYSTEM

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NOTE: Edit 3.2 to match project requirements.

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A. Concrete Encased Electrode:

Where available, use the building concrete grade beam to make a concrete encased main grounding electrode; conductor may be either reinforcing steel or copper ground cable:

1. Make one reinforcing bar, located in the bottom one-third of the footing, electrically continuous around the entire perimeter of the building. The reinforcing bar shall be at least #6 size and uncoated. Bond the reinforcing bars together by exothermically welding #4/0 AWG ground cable across splices.

2. Install a continuous #4/0 AWG ground cable in the bottom one-third of the grade beam around the entire perimeter of the building. Space cable from the bottom of the grade beam so it has at least 2 inches of concrete coverage.

B. Other Made Electrodes:

Where it is not possible to use the building grade beam as a concrete encased electrode, or the main grounding electrode must be supplemented, use one or more of the following made electrodes:

1. Install a counterpoise of #4/0 AWG ground cable located 5 ft outside the building perimeter and at least 6 ft from any lightning protection grounding. Install the counterpoise at least 3 ft below grade. Encase the counterpoise in a 2 inch envelope of ground electrode backfill material slurry.

2. Install one or more ground rods located 5 ft outside the building perimeter and at least 6 ft from any lightning protection grounding. Install ground rods in 6 inch diameter augered holes with at least 10 ft separation between rods. Backfill hole with a slurry of ground electrode backfill material.

C. Main Ground Electrode Ground Bar:

1. Install a main electrode ground bar in an accessible location in the main electrical room adjacent to the service entrance equipment.

2. Use #4/0 AWG ground cable with exothermic weld connections or compression grounding lug to connect the main electrode ground bar to the main grounding electrode or to other made electrodes.

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NOTE: Edit 3 and 4 to match project requirements. Main ground electrode ground bar extensions are intended for projects in reinforced concrete structures.

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[3. Main ground electrode ground bar extensions may be established at additional locations by installing ground bars or ground plates connected to the main electrode ground bar using #4/0 AWG insulated ground conductor with exothermic weld connections or compression grounding lug.]

4. Connections to the main ground electrode ground bar [or extensions] will be considered as connections directly to the main ground electrode.

D. Bond exterior underground metal water service piping systems within 50 ft of the building electrical service entrance to the main ground electrode bar; use #4/0 AWG ground cable. Comply with NFPA-70 requirements for bonding around water meters and insulating joints.

E. Bond the nearest building perimeter structural steel column or effectively grounded metal structure to the main ground electrode ground bar; use #4/0 AWG ground cable.

F. Bond each interior metal piping system to the main ground electrode bar; use #4/0 AWG insulated ground conductor and make connections at accessible locations.

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NOTE: Edit paragraph G to match project requirements. Use this paragraph only if there are structural steel columns. Do not use for structural metal stud or reinforced concrete systems.

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G. Bond the building perimeter structural steel columns to the main grounding electrode described in paragraph A [or B] above; use #4/0 AWG ground cable.

H. Label each conductor connected to the main ground electrode ground bar or main ground electrode ground bar extensions. Refer to Section 16195 - Electrical Identification for labeling materials and installation.

3.3 CIRCUIT AND SYSTEM GROUNDING

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NOTE: Edit 3.3 to match project requirements.

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A. Connect the service entrance equipment ground bus to the main electrode ground bar; use grounding conductor sized as shown on the Drawings or as required by ANSI/NFPA-70, Table 250-94.

B. In the service entrance equipment, connect the neutral bus to the ground bus in accordance with equipment manufacturer's instructions. Make no other neutral-to-ground connections on the load side of the service entrance disconnect.

C. Separately Derived Systems:

1. Connect ground bus of first disconnecting means for separately derived systems in the vicinity of the main electrical equipment room to the main electrode ground bar; use grounding conductor sized as shown on the Drawings or as required by ANSI/NFPA-70, Table 250-94.

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NOTE: Select sub-paragraph 2 or 3 to match project requirements.

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2. Connect ground bus of first disconnecting means for separately derived systems that are remote from the main electrical room to the nearest effectively grounded building structural steel column and the nearest effectively grounded metal water pipe; use grounding conductor sized as shown on the Drawings or as required by ANSI/NFPA-70, Table 250-94. Make connections at accessible locations.

[3. Connect ground bus of first disconnecting means for separately derived systems that are remote from the main electrical room to an extension of the main electrode ground bar if there is neither a nearby effectively grounded building structural steel column nor an effectively grounded metal water pipe; use grounding conductor sized as shown on the Drawings or as required by NFPA-70, Table 250-94.]

4. At the first system overcurrent device or disconnecting means, connect the neutral bus to the ground bus using a bonding jumper sized as required by ANSI/NFPA-70, Table 250-94. Make no other neutral-to-ground connections on the load side of the separately derived system disconnect.

5. Separately derived systems include dry type transformers, power distribution units, generators and uninterruptible power supplies.

3.4 ENCLOSURE AND EQUIPMENT GROUNDING

A. General: Provide permanent and effective equipment, enclosure, and raceway grounding in accordance with ANSI/NFPA 70, Table 250-95 requirements and as further specified or shown on the Drawings.

B. Provide an equipment ground bar, separate from any neutral bar, in all switchgear, switchboards, panelboards, transformers, motor control centers, starters, disconnect switches, cabinets, etc., for grounding the enclosure and for connecting other equipment and raceway ground conductors. Make connections to the ground bar using mechanical lugs or compression lugs.

C. Make connections and couplings on metallic conduit systems wrench tight.

D. Grounding Bushings:

1. Install grounding bushings on metallic conduit containing circuits rated 100 amperes and higher.

2. Install grounding bushings on metallic conduits entering enclosures through concentric, eccentric or oversize knockouts.

3. Install grounding bushings on metallic conduits that terminate to a metallic enclosure without effective electrical connection such as locknuts or threaded bushings.

4. Bond conduit grounding bushing lug to the equipment ground bar or ground lug in switchgear, switchboards, panelboards, transformers, motor control centers, starters, disconnect switches, cabinets, etc. Size bonding jumpers in accordance with ANSI/NFPA 70, Table 250-95.

E. Provide an insulated equipment grounding conductor for each feeder and branch circuit.

1. Install the grounding conductor within the common conduit or raceway with the related phase and neutral conductors and connect to the box or cabinet grounding terminal or grounding bus.

2. Size equipment ground conductor in accordance with ANSI/NFPA 70, Table 250-95 or as shown on the Drawings.

F. In each 15 or 20 ampere branch circuit outlet box and junction box, install a green colored washer head grounding screw with a minimum No. 12 equipment grounding conductor pigtail.

G. Connect receptacle grounding terminals to the equipment ground system using minimum No. 12 AWG equipment grounding conductor. Do not use a "self-grounding" receptacle strap as the only equipment grounding path.

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NOTE: Edit paragraphs H, I, J and K to match project requirements; delete if not needed.

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H. Connect ground lead of low voltage surge arrestor or transient voltage surge suppressor to the equipment ground bar of the protected switchgear, switchboard or panelboard. Make connections as short and straight as practical; follow manufacturer's instructions.

I. Bond raceways served from cable tray using conduit clamps or grounding bushings that are UL approved for the purpose.

J. Install an equipment grounding conductor in each cable tray; size conductor per ANSI/NFPA 70, Table 250-95, but not smaller than #6 AWG. Bond grounding conductor to each cable tray section using UL Listed cable tray ground clamps. Connect grounding conductor to ground bus of each enclosure or equipment item served by the cable tray.

K. Provide busways with a separate, internal equipment ground bus bar. Install separate insulated equipment ground conductor from the ground bus in the switchgear, switchboard, or distribution panel to the equipment ground bar terminal on busway. Size conductor in accordance with ANSI/NFPA 70, Table 250-95.

3.5 ISOLATED GROUND SYSTEM

A. Install an isolated ground system as shown on the Drawings to serve computer and laboratory instrument outlets.

B. In addition to the equipment ground bar, provide a separate, insulated, isolated copper ground bar in panelboards and switchboards supplying isolated ground circuits.

C. Run the isolated grounding conductor together with the phase, neutral, and equipment grounding conductors in isolated ground system feeder and branch circuit conduits.

D. Make the isolated ground conductor the same size as the associated phase conductors.

E. At the first isolated ground system phase conductor overcurrent device or disconnecting means, bond the isolated ground bus to the equipment ground bus. Make no other isolated ground to equipment ground connections on the load side of the separately derived system disconnect.

F. Connect the isolated ground conductors to the isolated ground bars in switchboards and panelboards and to the isolated ground terminals at receptacles and equipment.

3.6 COMMUNICATION SYSTEM GROUNDING

A. Install a communications system ground bar in each telephone and data closet on each floor or as shown on the Drawings.

B. Bond communications system ground bars to the main ground electrode ground bar in the main electrical closet using #4/0 AWG insulated ground conductor.

C. Communications system installers will connect surge protection equipment to the nearest communications system ground bar.

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NOTE: Edit 3.7 to match project requirements.

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3.7 SIGNAL REFERENCE GRID

A. Install a signal reference grid (SRG) on the concrete subfloor under raised computer flooring as indicated on the Drawings. Join pre-fabricated grid sections by exothermic welding. Position copper strip so sharp burrs on edge of strip face down.

B. Bond structural columns, conduits, water pipes, ducts, etc., entering the computer room to the SRG. Bond to the nearest intersecting point of SRG using #6 AWG grounding conductor.

C. Bond computer equipment to the SRG using low impedance riser (LIR).

1. Do not connect LIR to the SRG strip closest to the outside edges.

2. Cut LIR to the shortest possible length.

3. If length of LIR exceeds 24 inches, use two parallel LIR's. Make the second LIR 20% to 40% longer than the first and connect to equipment at opposite corners.

D. Bond power distribution units and power distribution panelboards to the SRG using LIR.

E. Bond every sixth raised floor pedestal in each direction to the nearest intersecting point of the SRG using #6 AWG grounding conductor. Keep conductors as short as possible

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NOTE: Edit 3.8 to match project requirements.

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3.8 OVERHEAD LINE GROUNDING

A. General: Comply with ANSI C2, "National Electrical Safety Code" for "Single-Grounded Systems," using two electrodes in parallel if a single electrode resistance to ground exceeds 25 ohms.

B. Separate lightning arrester grounds from other ground conductors.

C. Interconnect secondary neutral and tank of transformer and connect to ground.

D. Protect grounding conductors running on the surface of wood poles with molding of a type manufactured for this purpose. Extend from grade level up to and through communications and transformer spaces.

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NOTE: Edit 3.9 to match project requirements.

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3.9 UNDERGROUND DISTRIBUTION SYSTEM GROUNDING

A. Install a #4/0 AWG bare copper ground cable within the concrete envelope of each power and communications ductbank; connect to ground cable in manholes.

B. Ground metallic conduit exposed to contact in accordance with the requirements of NFPA 70. Use exothermic welded connections for concealed grounding connections.

C. Install continuous loop of #4/0 AWG bare copper ground cable around inside walls of each handhole or manhole at floor level.

1. Attach to walls using copper or cast bronze cable holder and masonry anchor.

2. Connect to duct bank ground cable using exothermic welds or approved non-reversible compression fittings.

3. Ground exposed metal parts, such as inserts, cable racks, pulling irons, ladders, cable shields, metallic conduits or duct bell ends to ground cable loop using No. 4 AWG stranded copper wire with exothermic welds or approved non-reversible compression fittings. Train conductors plumb or level around corners and fasten to manhole walls.

D. Ground non-current-carrying metallic items associated with manholes, substations, and pad-mounted equipment by connecting them to ground cable and grounding electrodes arranged as indicated on the Drawings.

3.10 FIELD QUALITY CONTROL

A. General: Perform on-site verification, certification and acceptance testing of the grounding installation during construction. Verification and testing will be witnessed by University designated representatives.

B. Notify the Contract Administrator ten (10) working days in advance of the expected completion of a grounding system installation. Verification and testing can be scheduled in parts or by area depending on the system and construction schedule.

C. Verify and certify that the following grounding installations have been made correctly:

1. The building grounding electrode system. This includes the bonding of the foundation reinforcing bars, bonding of the structural steel columns, and bonding of other metallic systems and other grounding electrode systems. This shall be done before concrete is poured.

2. Ground plates and grounding bars before concrete is poured or before wall partitions are installed.

3. All other underground grounding installation before concrete is poured or before backfilling.

4. The signal reference grid (SRG) before the raised flooring is installed.

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NOTE: Edit Paragraph D. and Section 16950 to match project requirements.

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D. Acceptance Testing: Perform acceptance testing and submit written reports to the Contract Administrator in accordance with the requirements of Section 16950. Tests will be witnessed by designated University representatives.

1. Perform ground-impedance measurements using the "fall-of-potential" method in accordance with IEEE 81, *Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials of a Grounding System*. Use instrumentation specifically designed for ground impedance testing as defined in Section 12 of the above guide. Provide sufficient spacing of test electrodes so that the plotted curves flatten in the 62% area of the distance between the item under test and the current electrode. When sufficient spacing of electrodes is impractical for the "fall-of-potential" method, perform ground-impedance measurements using either the "intersecting curves method" or the "slope method", references 40 and 41 in IEEE Std. 81.

2. Ground-impedance maximum values shall be as follows:

a. Equipment rated 1000 kVA and less: 5 Ohms
b. Equipment rated over 2500 kVA: 1 Ohm
c. Unfenced substations and pad-mounted equipment: 5 Ohms
d. Manhole grounds: 10 Ohms

3. Test equipment ground resistances for the following items. Measure resistance between the equipment item and the Main Ground Electrode Ground Bar. Use the "two-point method" of IEEE Std. 81.

a. Transformers
b. Switchgear and Switchboards
c. Panelboards
d. Generators
e. Motor Control Centers
f. Motors larger than 1 HP
g. UPS Systems

4. Equipment ground maximum test values shall be as follows:

a.	Equipment rated 100 amps or less:	0.20 Ohm
b.	Equipment rated 400 amps or less:	0.05 Ohm
c.	Equipment rated 1000 amps or less:	0.02 Ohm
d.	Equipment rated over 1000 amps:	0.01 Ohm

E. Where ground-impedances or equipment ground resistances exceed specified values, and if directed by the Contract Administrator, modify the grounding system to reduce resistance values.

F. Prepare test reports, certified by the testing organization, of the ground resistance at each test location. Include observations of weather and other phenomena that may affect test results. Describe any measures taken to improve test results.

END OF SECTION